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SPECIFICATION

[Title of the Invention] SILICON WAFER CLEANING METHOD AND WASHED SILICON WAFER

[Scope of Claim for a Patent]

[Claim 1] A silicon wafer cleaning method for cleaning an annealed silicon wafer, comprising:

a step of carrying out oxidation treatment having an anisotropy with respect to crystal orientation of a silicon single crystal constituting the wafer; and

a step of cleaning the oxidized silicon wafer with hydrofluoric acid.

[Claim 2] The silicon wafer cleaning method according to claim 1, wherein the oxidation treatment is carried out by cleaning with ozonized water.

[Claim 3] The silicon wafer cleaning method according to claim 1 or 2, wherein oxidation treatment process with ozonized water is executed just after the oxidation treatment process and cleaning process with hydrofluoric acid.

[Claim 4] The silicon wafer cleaning method according to claim 2 or 3, wherein the density of the ozonized water is 10 to 60 ppm.

[Claim 5] The silicon wafer cleaning method according to claim 1 to 4, wherein the density of the hydrofluoric acid is 0.5 to 2%.

[Claim 6] A silicon wafer wherein micro roughness under spatial frequency of  $20/\mu\text{m}$  is 0.3 to 1.5  $\text{nm}^3$  in terms of power spectrum density.

[Detailed Description of the Invention]

[0001]

[Technical Field Pertinent to the Invention]

The present invention relates to a silicon wafer cleaning method and more particularly to a silicon wafer cleaning method for cleaning a high-temperature annealed silicon wafer with its surface structure maintained and a washed silicon wafer.

[0002]

[Prior Art]

The surface of a silicon wafer flattened up to atomic level has a so-called step terrace structure in which layers of silicon atoms are formed in step-like formation. As shown in Fig. 1, this step terrace structure is comprised of a terrace face 1, which is a sliced face of the wafer and a step face 2 in which minute steps on atomic level are formed with respect to the terrace face 1.

[0003]

By annealing a silicon wafer at high temperatures of 1000 to 1200°C under, for example, an environment of hydrogen gas or the like, usually, a step composed of one to three layers of silicon atoms, that is, a step terrace structure having atomic level step on the surface thereof is formed. This is formed because silicon atoms on the surface of a wafer are rearranged for stabilization under high temperature hydrogen environment.

[0004]

By reducing an off angle of silicon crystal further, the terrace width of the aforementioned step terrace structure is

increased, so that the surface of the annealed silicon wafer is flattened up to atomic level.

[0005]

In silicon wafer manufacturing process, a silicon wafer whose surface is flattened by the aforementioned hydrogen annealing processing or the like is sent to cleaning process in order to remove particles and metallic foreign matter from the surface of the wafer.

Conventionally, RCA cleaning has been employed as a general method in this cleaning process.

In the RCA cleaning, SC-1 cleaning liquid composed of ammonia: hydrogen peroxide: pure water = 1:1 to 2:5 to 7 (volume mixing ratio) is used as a cleaning liquid to remove, for example, mainly organic pollutant and adhering particles. Further, to remove mainly silicon oxide layer and surface metallic foreign matter, thin hydrofluoric acid (DHF liquid) composed of HF: pure water = 1:99 is used, and further to remove mainly surface metallic foreign matter, SC-2 cleaning liquid composed of muriatic acid: hydrogen peroxide: pure water = 1:1 to 2:5 to 7 (volume mixing ratio) is used.

[0006]

However, in the RCA (SC-1) cleaning, silicon on the wafer surface undergoes anisotropic etching with ammonia, so that the step terrace structure formed by annealing processing with hydrogen gas or the like is vanished, thereby worsening the surface roughness (micro roughness).

[0007]

As another cleaning method, a cleaning method using mixing solution of hydrogen fluoride and ozonized water has been disclosed in, for example, a patent document 1 mentioned below.

According to this method, oxide film is formed on the wafer surface with ozonized water by injecting hydrogen fluoride and ozonized water to the wafer surface at the same time.

Consequently, a contact angle between the wafer surface and hydrogen fluoride is made small and the surface is likely to be wet, so that the particles can be removed without exposing silicon layer.

[0008]

However, when hydrogen fluoride and ozonized water are used in mixture, oxide film is formed unequally within a plane on the wafer surface. Thus, this method is difficult to suppress deterioration of the surface roughness (micro roughness).

[0009]

[Patent Document 1]

Japanese Patent Publication No.10-340876 (page 3)

[0010]

[Problem to be solved by the Invention]

With recently intensified integration of semiconductor circuit, miniaturization of a formed device has been demanded and for example, gate oxide film thickness of about 3 nm has been demanded in processing on the level of 0.13 nm in terms of line width.

Corresponding to such a decreased thickness of the oxide film, the fine roughness of the wafer, so-called micro roughness

has been demanded to be reduced in size further.

[0011]

Usually, a silicon wafer is sliced so as to have its crystal orientation of Si (100) plane or Si (111) plane when it is cut out from a single crystal ingot. Particularly, in case of the Si (100) plane, flattening on atomic level is difficult and therefore, the micro roughness has been demanded to be reduced as much as possible.

[0012]

However, to remove particles and metallic foreign matter after annealing or obtain a wafer having a clean surface, the wafer cleaning process is an absolutely necessary process although the surface roughness (micro roughness) is worsened as described above.

[0013]

Therefore, technology capable of cleaning a wafer with its step terrace structure on an annealed wafer surface maintained, despite any crystal orientation of the wafer surface has been demanded.

[0014]

The present invention has been accomplished to solve the above-described technical problem and an object of the present invention is to provide a cleaning method of silicon wafer and a washed silicon wafer capable of removing such surface adhering pollutant as particles and metallic foreign matter with the surface structure of silicon wafer flattened up to atomic level by annealing processing maintained.

[0015]

[Means for solving the Problem]

The silicon wafer cleaning method of the present invention is characterized by comprising: a step of carrying out oxidation treatment having an anisotropy with respect to crystal orientation of a silicon single crystal constituting the wafer; and a step of cleaning said oxidized silicon wafer with hydrofluoric acid.

According to the cleaning method, because the wafer flattened up to atomic level by annealing processing is washed with hydrofluoric acid after a predetermined silicon oxidation treatment, adhering particles, metallic foreign matter and the like can be removed without damaging the wafer surface structure.

[0016]

Preferably, the oxidation treatment is carried out by cleaning with ozonized water.

Oxidation of the silicon single crystal with ozonized water is preferable because oxidation progress velocity is equal in all crystal orientations and oxidation is progressed with the surface structure of the annealed wafer maintained.

[0017]

It is preferable that oxidation treatment process with ozonized water is executed just after the aforementioned oxidation treatment process and cleaning process with hydrofluoric acid.

By executing the oxidation treatment with ozonized water again after oxide film is removed completely in the hydrofluoric

acid cleaning process, a wafer surface structure formed by annealing processing can be maintained completely.

[0018]

Preferably, the density of the ozonized water is 10 to 60 ppm while the density of the hydrofluoric acid is 0.5 to 2%.

By cleaning in the above-mentioned density range, the oxidation treatment time and cleaning time can be adjusted easily.

[0019]

The washed silicon wafer of the present invention is characterized in that micro roughness under spatial frequency of  $20/\mu\text{m}$  is 0.3 to  $1.5 \text{ nm}^3$  in terms of power spectrum density.

In such a silicon wafer, preferably, micro roughness after annealing is maintained, so that a cleaning effect by the aforementioned cleaning method is recognized.

[0020]

[Embodiments]

Hereinafter the present invention will be described further in detail.

The silicon wafer cleaning method of the present invention is characterized in that an annealed silicon wafer is subjected to hydrofluoric acid cleaning after oxidation treatment having anisotropy with respect to crystal orientation of a silicon single crystal constituting the wafer.

That is, after a predetermined silicon oxidation treatment, by cleaning an annealed wafer with hydrofluoric acid, adhering particles, metallic foreign matter and the like can be removed

by cleaning without damaging the surface structure of a wafer flattened up to atomic level.

[0021]

The aforementioned oxidation treatment is carried out by cleaning with ozonized water.

Oxidation of silicon single crystal with ozonized water does not have dependency on crystal orientation. That is, because oxidation progress velocity is equal with respect to all crystal orientations, the annealed wafer is oxidized with its wafer surface structure maintained.

[0022]

Fig. 2 shows the relation between treatment time with ozonized water and the thickness of chemical oxidized film on the silicon wafer surface.

In any case where the crystal lattice orientation is Si (111) plane or Si (100) plane as shown in Fig. 2, the thickness of chemical oxide film with ozonized water becomes substantially constant and its oxidation velocity is substantially equal.

[0023]

Fig. 3 shows changes in existence ratio of Si atom coordination number measured by X-ray photoelectron spectroscopy (XPS) analysis with a time passage about a case where a silicon wafer is washed with 1% hydrofluoric acid after that wafer is treated with 20 ppm ozonized water and a case of SC-1 cleaning.

As shown in Fig. 3, formation ratio of Si (IV) is higher and a change thereof with a passage of cleaning time is smaller

in case where hydrofluoric acid cleaning is carried out after treatment with ozonized water than in case of the SC-1 cleaning.

The oxide film, which is formed with ozonized water, is formed with a more stabilized oxidation condition as compared to the chemical oxide film formed by the conventional RCA cleaning with the SC-1 liquid or the like.

[0024]

The hydrofluoric acid cleaning is carried out to decompose and remove oxide film formed on the wafer surface by the oxidation treatment and remove adhering particles, metallic foreign matter and the like on the wafer surface with step terrace structure on the wafer surface formed by annealing processing maintained.

Because this hydrofluoric acid cleaning is executed after oxidation treatment with ozonized water, the wafer surface formed by annealing processing can be washed without damaging the step terrace structure on the wafer surface formed by the annealing or deteriorating surface roughness (micro roughness) on atomic level.

[0025]

Further, it is preferable that the oxidation treatment process with ozonized water is executed just after the aforementioned oxidation treatment process and cleaning process with hydrofluoric acid.

If cleaning time is short in the aforementioned hydrofluoric acid cleaning process, a silicon protrusion is formed on the terrace surface of the silicon wafer. This protrusion is about 10 to 30 nm in width and about 0.2 to 0.5

nm in height and possesses crystallinity. The protrusion is decreased by etching action as the hydrofluoric acid cleaning time is increased and finally, a flat terrace without any protrusion is formed.

Further, by executing the oxidation treatment with ozonized water after the hydrofluoric acid cleaning process, the silicon wafer surface is oxidized equally without indicating crystal orientation dependency. Thus, after the hydrofluoric acid cleaning process, the surface is oxidized with its configuration maintained, so that the wafer surface does not become rough.

However, if cleaning process with pure water or the like is passed before the oxidation process with ozonized water, the silicon wafer is oxidized unequally through the protrusion, so that the wafer surface becomes rough.

[0026]

The aforementioned chemical fluid cleaning with ozonized water or the like or hydrofluoric acid cleaning can be executed by spraying or dipping like an ordinary cleaning method.

In a case by spraying, the cleaning method of the present invention can be executed by means of, for example, a sheet-feeding-type cleaning apparatus shown in Fig. 4.

In the sheet-feeding type cleaning apparatus shown in Fig. 4, a silicon wafer 2 is disposed on a rotation table 3 through a holding pin 4 within a spin cup 1. The rotation table 3 is rotated by a driving force of a motor 6 through a drive shaft 5 connected to the bottom thereof.

It is so adjusted that ozonized water or hydrofluoric acid supplied from an ozonized water tank 7 or a hydrofluoric acid tank 8 is sprayed on the silicon wafer 2 appropriately.

Waste fluid after the cleaning is discharged to the bottom of the spin cup 1.

[0027]

Although the density of the aforementioned ozonized water is not restricted, it is preferred to be 10 to 60 ppm in viewpoints of adjustment of the oxidation treatment time.

Further, the density of the hydrofluoric acid is preferred to be 0.5 to 2% in viewpoints of adjustment of the cleaning time.

In the meantime, the oxidation treatment time and cleaning time change depending on the size of the wafer, the density of the ozonized water, the density of hydrofluoric acid or the like and it is set up appropriately.

[0028]

Preferably, a wafer which the cleaning method of the present invention is applied to is an annealed wafer so that its surface is flattened up to atomic level and in which the step terrace structure is formed on the wafer surface as shown in Fig. 1.

After a silicon single crystal obtained according to Czochralski (CZ) method, floating zone (FZ) method and the like is sliced, a mirrored silicon wafer substrate (prime wafer) is annealed under an environment of reduction gas such as hydrogen, ammonia or inactive gas such as argon, helium, neon at high temperatures of 1000 to 1400°C for 0.5 to 24 hours. Usually, the silicon wafer is annealed under hydrogen gas environment

at high temperatures of about 1200°C for about an hour.

The annealed epitaxial wafer, the annealed SOI wafer and the like can obtain the effect of the present invention even if they have the above-described structure.

[0029]

As for the fine surface roughness (micro roughness) of the annealed wafer, for example, when it is measured with an atomic force microscope (AFM), the wafer surface is preferred to be such that central line average roughness per  $1 \mu\text{m}^2$  is about 0.05 to 1 nm, the average roughness ( $R_{\text{ms}}$ ) is about 0.05 to 0.1 nm and the maximum roughness ( $R_{\text{max}}$ ) is about 0.5 to 1.0 nm, that is, the step is preferred to be composed of 1 to 10 layers of silicon atoms, most preferably, 1 to 3 layers.

[0030]

The cleaning method of the present invention is capable of cleaning not only in case where the crystal lattice orientation of the silicon wafer is on Si (111) plane but also in case of the Si (100) plane considered relatively difficult to be flattened up to atomic level, without generating anisotropy. Thus, it is possible to maintain a step terrace structure of the wafer surface formed by annealing processing.

[0031]

Fig. 5 shows the relation between the spatial frequency ( $/\mu\text{m}$ ) and power spectrum (PSD) ( $\text{nm}^3$ ) of a silicon wafer washed according the above-mentioned cleaning method.

As shown in Fig. 5, the silicon wafer washed according to the aforementioned cleaning method presents substantially

the same tendency as a PSD after hydrogen annealing and thus, micro roughness is maintained.

On the other hand, although the silicon wafer after the SC-1 cleaning presents substantially the same tendency as the PSD after hydrogen annealing under spatial frequency of 1 to  $10/\mu\text{m}$ , no PSD peak originating from a step terrace structure in the vicinity of  $2/\mu\text{m}$  in terms of spatial frequency spatial frequency is recognized.

That is, although the step terrace structure produced by the hydrogen annealing is vanished by the SC-1 cleaning, the micro roughness after the hydrogen annealing is maintained in the silicon wafer washed according to the cleaning method of the present invention.

[0032]

As evident from the graph shown in Fig. 5, if in the silicon wafer washed according to the cleaning method of the present invention, micro roughness under spatial frequency of  $20/\mu\text{m}$  is in a range of 0.3 to  $1.5 \text{ nm}^3$  in terms of power spectrum, preferably, the micro roughness after the hydrogen annealing is maintained and the effect of the cleaning method of the present invention can be found out.

[0033]

[Examples]

Although the present invention will be described in detail with reference to the examples, the present invention is not restricted to examples described below.

[Example 1]

First, a mirrored P-type Si (100) prime wafer 8 inch in diameter, annealed under hydrogen environment at 1200°C for an hour, was prepared.

This wafer was subjected to hydrofluoric acid cleaning after oxidation treatment with 30 ppm ozonized water.

The central line average roughness ( $R_a$ ) per  $1 \mu\text{m}^2$ , average roughness ( $R_{ms}$ ), the maximum roughness ( $R_{max}$ ) and absence/presence of step terrace structure per  $3 \mu\text{m}^2$  were evaluated through the atomic force microscope (AFM).

Table 1 shows these results.

As for the wafer after the cleaning, Fig. 5 shows the relation between spatial frequency ( $/\mu\text{m}$ ) and power spectrum (PSD) ( $\text{nm}^3$ ).

For comparison, a mirrored wafer and an annealed wafer were evaluated about their surface roughness (micro roughness) and whether or not the step terrace structure existed like example 1.

[0034]

[Comparative example 1]

A mirrored P-type Si (100) prime wafer 8 inch in diameter was annealed at 1200°C under hydrogen environment for an hour.

This wafer was subjected to the RCA (SC-1) cleaning.

About this wafer, its surface roughness (micro roughness) and absence/presence of step terrace structure were evaluated like the example 1.

Table 1 shows these results.

Fig. 5 shows a graph indicating the relation between spatial

frequency ( $/\mu\text{m}$ ) and power spectrum (PSD) ( $\text{nm}^3$ ) of a washed wafer.

[0035]

[Comparative example 2]

A mirrored P-type Si (100) prime wafer 8 inch in diameter was annealed at  $1200^\circ\text{C}$  under hydrogen environment for an hour.

This wafer was washed with mixing solution of hydrogen fluoride and ozonized water.

About this wafer, its surface roughness (micro roughness) and absence/presence of step terrace structure were evaluated in the same way as the example 1.

Table 1 shows these results.

[0036]

[Table 1]

	$R_a$ (nm)	$R_{ms}$ (nm)	$R_{max}$ (nm)	Step terrace structure
After mirror treatment	0.2	0.25	3.0	Absence
After annealing	0.07	0.09	0.9	Presence
Example 1	0.07	0.09	1.0	Presence
Comparative example 1	0.2	0.25	2.5	Absence
Comparative example 2	0.19	0.24	2.4	Absence

[0037]

As shown in Table 1, in case where the conventional RCA cleaning was performed (comparative example 1) and it was washed with mixing solution of hydrogen fluoride and ozonized water (comparative example 2), the surface roughness was increased to substantially the same level as a wafer before the annealing treatment was performed. Further, the step terrace structure

formed on the wafer surface was vanished by the annealing treatment.

On the other hand, if the oxidation treatment with ozonized water and cleaning with hydrofluoric acid were carried out (example 1), the surface roughness was hardly changed as compared to the wafer surface roughness after the annealing treatment. Further, it was recognized that flatness on atomic level constituted of terrace and step was maintained.

[0038]

When oxidation treatment with ozonized water and hydrofluoric acid cleaning were executed as shown in the graph of Fig. 5 (example 1), substantially the same tendency as the PSD after hydrogen annealing treatment was presented, so that it was recognized that micro roughness was maintained.

On the other hand, in case of the SC-1 cleaning (comparative example 1), no PSD peak originating from the step terrace structure in the vicinity of  $2/\mu$  in terms of spatial frequency was recognized, and then, it was recognized that the step terrace structure was vanished.

[0039]

[Example 2]

After the oxidation treatment and cleaning were carried out in the example 1, wafer oxide film pressure resistance (TDDB) characteristic was evaluated.

In the meantime, for the TDDB evaluation, a voltage was applied to each of 80 cells 10 to 50 times repeatedly under the condition that gate oxide film thickness was 10 nm, an electrode

area was 1 mm<sup>2</sup>, an applied voltage was 9 MV/cm, application time was 100 seconds and temperature was 120°C and the number of cells in which initial accidental defect occurred was measured.

Table 2 indicates this result.

[0040]

[Comparative examples 3, 4]

After the cleaning was carried out in the comparative examples 1, 2, wafer oxide film pressure resistance (TDDB) characteristic was evaluated in the same way as the example 2.

Table 2 shows this result.

[0041]

[Table 2]

Repetition number	10	20	30	40	50
Example 2	0	0	0	0	0
Comparative example 3	0	1	3	11	12
Comparative example 4	0	2	3	10	13

[0042]

As shown in Table 2, if the RCA cleaning is carried out (comparative example 3) and if the cleaning is executed with mixing solution of hydrogen fluoride and ozonized water (comparative example 4), the surface roughness of the wafer was remarkable and the step terrace structure was vanished as shown in the comparative example 1 of Table 1. Thus, it was recognized that oxide film pressure resistance characteristic was deteriorated due to repeated application of 40 times or more.

On the other hand, if oxidation treatment with ozonized water and cleaning with hydrofluoric acid were executed (example

2), because flatness on atomic level constituted of terraces and steps was maintained after the cleaning as well, it was recognized that no deterioration in oxide film pressure resistance characteristic was generated despite the repeated applications of up to 50 times.

[0043]

[Example 3]

A mirrored P-type Si (100) wafer, whose off angle in  $\langle 100 \rangle$  direction was  $0.04^\circ$  or less, was annealed under hydrogen environment at  $1200^\circ\text{C}$  for an hour.

This specimen wafer was oxidized for 30 seconds with 20 ppm ozonized water using the single-sheet feeding type cleaning apparatus shown in Fig. 4 and washed by changing the cleaning time using 1% hydrofluoric acid.

Whether or not the surface of the specimen wafer was changed to hydrophobic during cleaning with hydrofluoric acid was recognized visually.

Table 3 shows the result. In Table 3, O indicates that the wafer surface was changed to hydrophobic, x indicates that the wafer surface was hydrophilic and  $\Delta$  indicates an intermediate state between both.

Just after cleaning with hydrofluoric acid, the specimen wafer was oxidized with 20 ppm ozonized water for 30 seconds.

After the cleaning was terminated, the surface structure of the specimen wafer ( $3\ \mu\text{m} \times 3\ \mu\text{m}$ ) and surface average roughness ( $R_{\text{ms}}$ ) were measured with the atomic force microscope (AFM).

Table 3 shows this result.

[0044]

[Table 3]

Hydrofluoric acid cleaning time (sec)	$R_{ms}$ (nm)	Surface condition
0	0.07	x
3	0.08	x
7	0.12	x
15	0.15	$\Delta$
20	0.09	O
30	0.07	O

[0045]

As a result of the above-described cleaning, although in the example 3, the step terrace structure of a silicon wafer just after hydrogen annealing was maintained on every specimen wafer, it was recognized that the surface average roughness ( $R_{ms}$ ) differed depending on hydrofluoric acid cleaning time as shown in Table 3.

Further, as shown in Table 3, to maintain the surface structure of hydrogen-annealed silicon wafer completely, it is preferable to prolong the hydrofluoric acid cleaning time sufficiently so as to keep the wafer surface hydrophobic.

[0046]

[Reference example]-----

Like the example 3, a specimen wafer which passed oxidation treatment process with ozonized water and hydrofluoric acid cleaning process was washed with pure water for 30 seconds and then subjected to oxidation treatment with 20 ppm ozonized water.

After the cleaning was terminated, the surface structure and surface average roughness ( $R_{ms}$ ) of the specimen wafer ( $3\ \mu\text{m} \times 3\ \mu\text{m}$ ) were measured with an atomic force microscope (AFM).

For comparison, Fig. 6 shows a graph indicating the relation between spatial frequency ( $1/\mu\text{m}$ ) and power spectrum (PSD) ( $\text{nm}^3$ ) regarding not only the above-mentioned washed wafer but also a wafer subjected to the hydrogen annealing and a wafer only washed with extrapure water after the oxidation treatment with ozonized water and hydrofluoric acid cleaning.

[0047]

As a result, although the silicon wafer step terrace structure just after hydrogen annealing was maintained, the surface average roughness ( $R_{ms}$ ) was 0.15 nm.

As evident from the graph of Fig. 6, if oxidation treatment with ozonized water was executed again after hydrofluoric acid cleaning, substantially the same tendency as the PSD after hydrogen annealing was presented and it was recognized that micro roughness was maintained.

On the other hand, in case where extrapure water cleaning was executed after hydrofluoric acid cleaning, if comparing with the PSD peak after hydrogen annealing, deterioration of micro roughness was remarkable particularly under spatial frequency of  $3/\mu\text{m}$  or more, although the PSD peak originating from the step terrace structure was recognized in the vicinity of  $2/\mu\text{m}$  in terms of spatial frequency and thus, it was found that a number of protrusions were formed on the terrace face.

Therefore, to maintain the surface structure of hydrogen

annealed silicon wafer more completely, it is preferable to carry out the oxidation treatment with ozonized water without any cleaning treatment with pure water or the like immediately after cleaning with pure water or the like.

[0048]

As described above, according to the silicon wafer cleaning method of the present invention, it is possible to remove surface adhering pollutant such as particles and metallic foreign matter with the surface structure of the silicon wafer flattened up to atomic level by annealing processing maintained.

According to the cleaning method of the present invention, by carrying out the oxidation treatment with ozonized water immediately after oxidation treatment with ozonized water and hydrofluoric acid cleaning, flattening on atomic level can be achieved completely.

Because in the wafer washed according to the cleaning method of the present invention, micro roughness after annealing is maintained and its oxide film pressure resistance characteristic is excellent, the present invention can contribute to provision of a silicon wafer preferable for formation of a micro semiconductor device.

[Brief Description of Drawings]

[Fig. 1]

Fig. 1 is a schematic diagram showing a magnified surface of an annealed wafer.

[Fig. 2]

Fig. 2 is a graph showing the relation between a treatment

time with ozonized water and the thickness of chemical oxide film on the silicon wafer surface.

[Fig. 3]

Fig. 3 is a graph showing changes with a time passage of existence ratio of Si atom coordination number measured by XPS analysis about a case where a silicon wafer is washed with 1% hydrofluoric acid after it is treated with 20 ppm ozonized water and about a case of SC-1 cleaning.

[Fig. 4]

Fig. 4 is a schematic diagram showing an example of the sheet-feeding type cleaning apparatus for executing the cleaning method of the present invention.

[Fig. 5]

Fig. 5 is a graph indicating the relation between spatial frequency ( $/\mu\text{m}$ ) of a wafer after various kinds of cleaning and power spectrum (PSD) ( $\text{nm}^3$ ).

[Fig. 6]

Fig. 6 is a graph indicating the relation between spatial frequency ( $/\mu\text{m}$ ) of a wafer after various kinds of cleaning and power spectrum (PSD) ( $\text{nm}^3$ ) in a reference example.

[Description of Reference Numerals]

- 1: spin cup
- 2: silicon wafer
- 3: rotation table
- 4: holding pin
- 5: drive shaft
- 6: motor

7: ozonized water tank

8: hydrofluoric acid tank

11: terrace face

12: step face



Fig.1

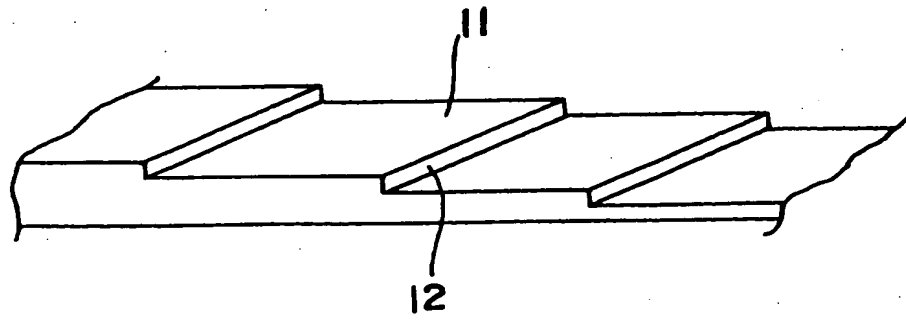


Fig.2

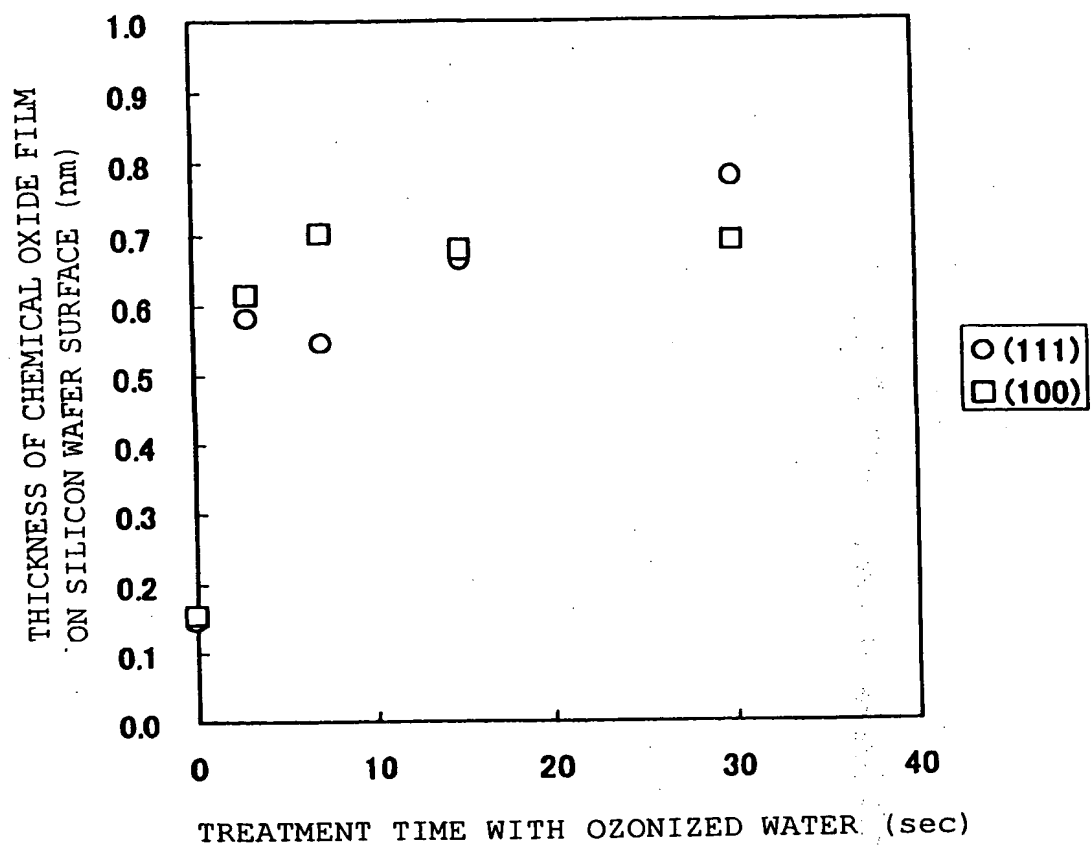


Fig. 3

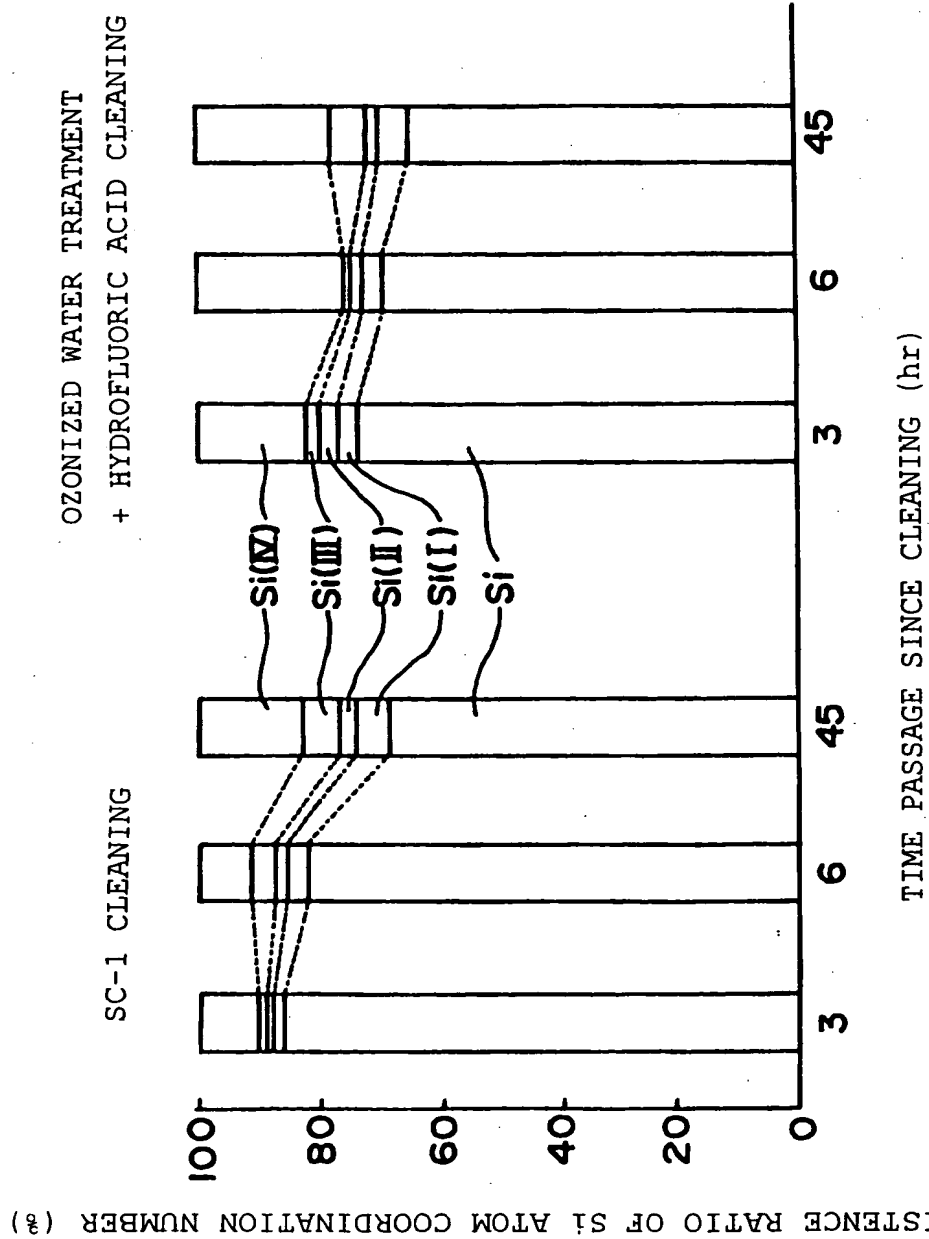


Fig. 4

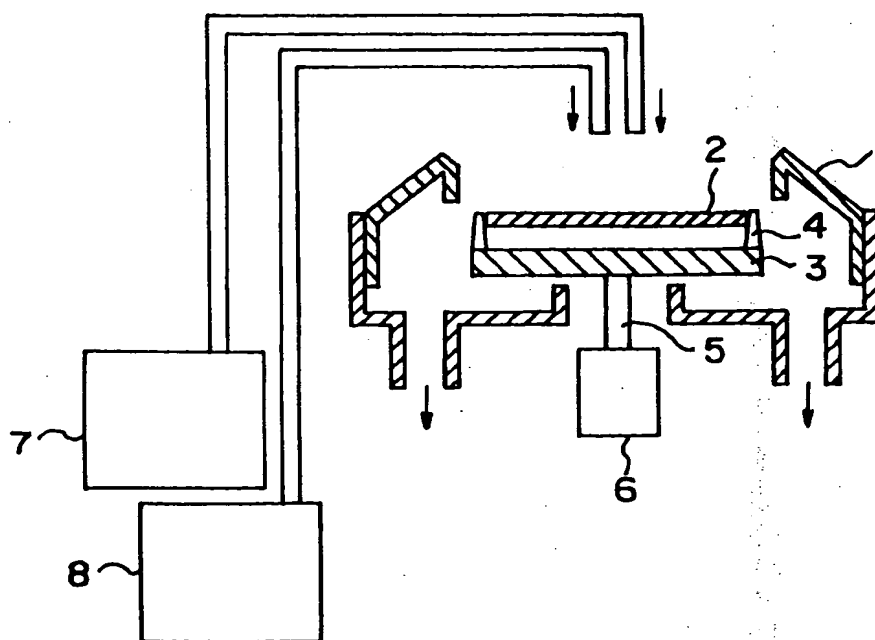


Fig.5

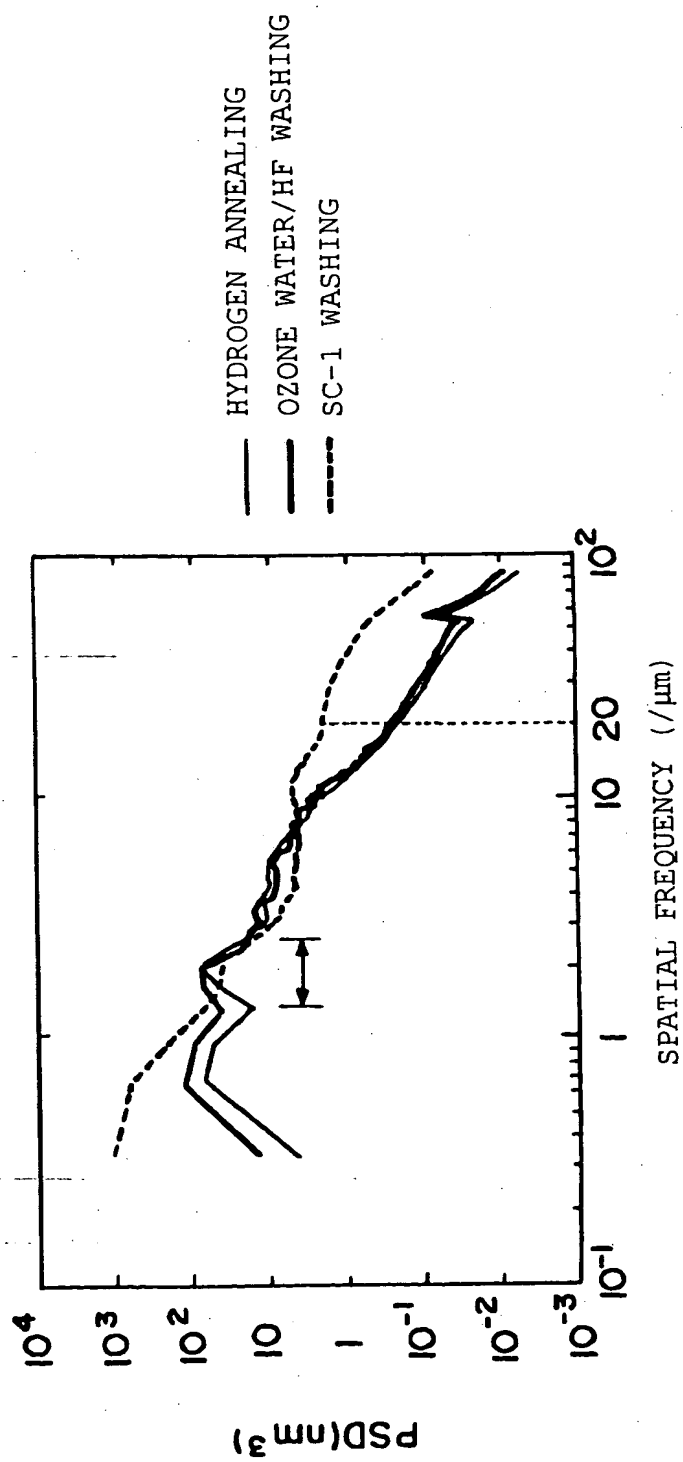
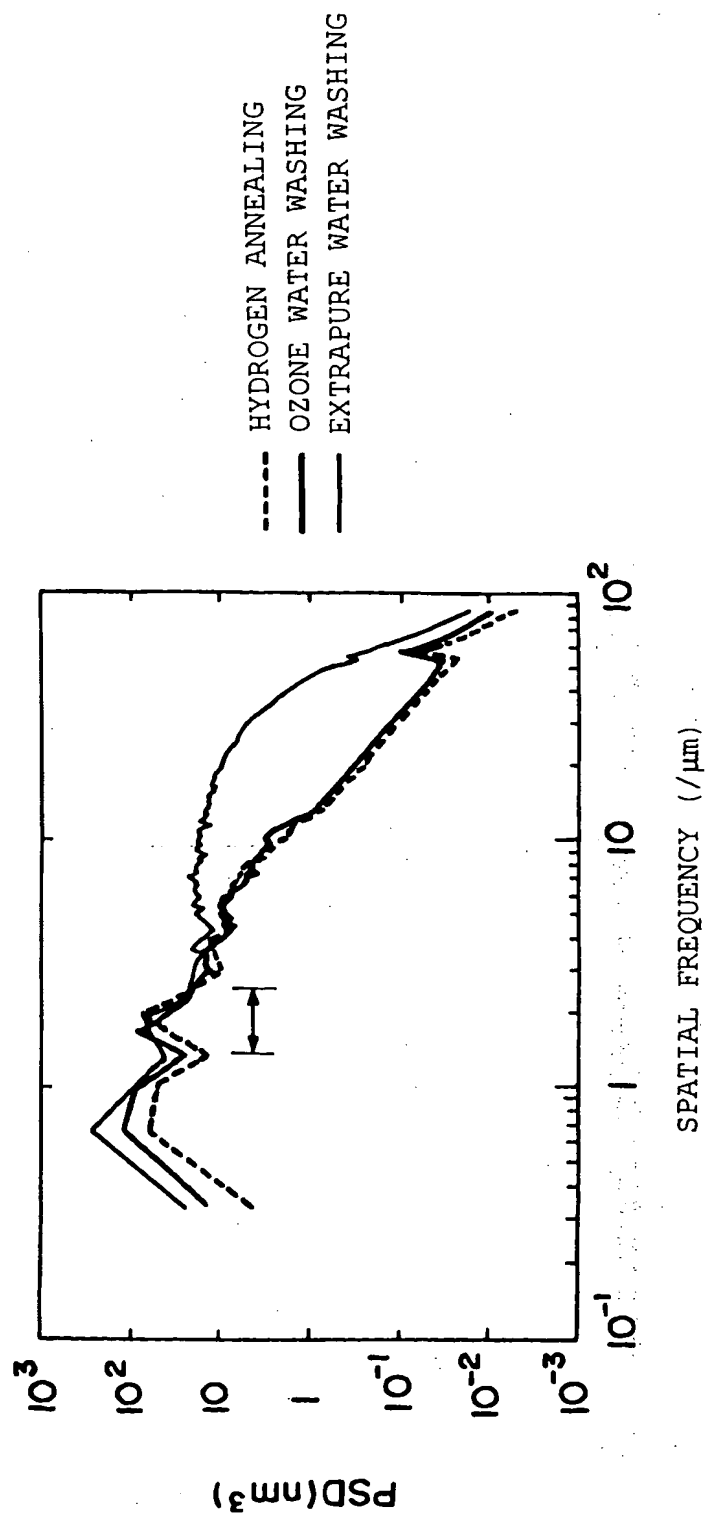


Fig. 6





[Name of Document]

ABSTRACT

[Summary]

[Subject] Providing a silicon wafer cleaning method capable of removing surface adhering pollutant as particles and metallic foreign matter with the surface structure of silicon wafer flattened up to atomic level by annealing processing maintained.

[Solving Means] A silicon wafer in which micro roughness under spatial frequency of  $20/\mu\text{m}$  is 0.3 to  $1.5 \text{ nm}^3$  in terms of power spectrum density is obtained according to a wafer cleaning method characterized by comprising a step of carrying out oxidation treatment without having dependency upon crystal orientation of silicon single crystal constituting a wafer and a step of cleaning the silicon wafer subjected to the oxidation treatment with hydrofluoric acid.

[Selected Diagram]

None